

New analysis in the field of open cluster Collinder 223

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Abstract

The present study of the open cluster Collinder 223 (Cr 223) has been mainly depended on the photoelectric data of Clariá & Lapasset (1991); hereafter CL91. This data of CL91 has been used with the cluster's image of AAO-DSS¹ in order to re-investigate and improve the main parameters of Cr 223. Stellar count has been achieved to determine the stellar density, the cluster's center and the cluster's diameter. In addition, the luminosity function, mass function, and the total mass of the cluster have been estimated.

Key words: (Galaxy:) open clusters and associations: individual: Cr 223.

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1. Introduction

The open cluster Cr 223 (C1028-595) situated in the Carina spiral feature of the southern Milky Way with 2000.0 coordinates $\alpha = 10^h30.5^m$, $\delta = -59^\circ49'$, $\ell = 286.2^\circ$, $b = -1.9^\circ$. Trumpler (1930) classified this cluster as a detached cluster with little central concentration and a medium range in the brightness of the stars (II-2p system). Collinder (1931) described this cluster as a system of 38 stars at a distance of 2630 pc distributed over a field of 8 arcmin.

110 stars in the cluster region have been studied by CL91 used the broadband *UBV* system and moreover seven probable red giants have been observed used the intermediate-band of *DDO* system. CL91 proved that these stars represented a genuine open cluster of only *B-type* stars that extends over a *V-range*

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¹ AAO: Anglo-Australian Observatory - DSS: Digitized Sky Surveys; taken from "SIMBAD" (<http://simbad.u-strasbg.fr>)

of about 11-14 mag. The identification chart of Cr 223 has been taken from Hogg (1965) and presented in Figure 1 of CL91. It is defined a radius of about 7.5 arcmin from the apparent center of the chart (near the star no. 77). CL91 described their work as a preliminary photometric study of Cr 223. Therefore some of the present parameters e.g., the luminosity and mass functions are preliminary also. So that more deep studies (CCD observations) of the cluster Cr 223 would be needed for more precisely determination of these parameters.

In the present work, reddening, distances, cluster's center, cluster's diameter, stellar density, age, membership analysis, luminosity function, mass function, and the total mass of the cluster have been estimated.

2. HR-Diagrams

The main photometrical parameters of the cluster (membership, reddening and distance) are depending mainly on HR-diagrams of that cluster, i.e. color-color (CC) diagram $[(U-B)-(B-V)]$, short and long wavelengths color-magnitude diagrams CMDs $[V-(U-B) \text{ \& } V-(B-V)]$.

2.1. Membership analysis

The uncertainty about membership increases for faint stars those are merging with the crowded galactic field. To discriminate between cluster members and field stars, the criteria of Clariá & Lapasset (1986) has been applied and the members have been chosen to verify the two conditions:

(1) its location in the two CMDs must correspond to the same evolutionary stage in the cluster, and (2) its location in the (CC) diagram must be close to the cluster main sequence, the maximum departure accepted being about 0.1 mag.

CL91 classified 46 of 110 stars as members including two blue stragglers (nos. 35 & 80); and one red giant (no. 75); and three probable members (nos. 30, 81 & 95). They classified about 60 stars as non members. For more details about the field stars see CL91.

Applying the above criteria after separating the giant stars and field ones, it is found that three stars could be added to the cluster Cr 223 as members (nos. 23, 31 & 32). Although these three new members are quite away from the cluster center, they lie inside the cluster's extended diameter (area) that estimated in section 6 of this work. On the other hand, their ranges of distance and reddening are found in agreement with those of the cluster's members.

2.2. Reddening and distance

The presence of interstellar matter throughout the spiral arms of the Galaxy makes the distance determination of the galactic clusters somewhat difficult where the starlight is frequently absorbed and scattered.

CL91 assumed that the cluster Cr 223 has some differential reddening, and for that reason they used equations (2) and (8) of Garcia, Clariá & Levato (1988) to dereddened stars individually with standard deviation of 0.03 mag.

In the present work, reddening (which is the importance parameter in deriving distance) has been estimated simultaneously with the apparent distance modulus with a standard deviation of 0.015 mag. These two parameters are estimated by fitting the standard zero-age main sequence *ZAMS* of Schmidt-Kaler (1982) to the lower envelope of the points in both CMDs of the cluster. Many fittings have been applied to reach the best corresponding values of reddening at the same distance moduli. The evolved stars have been excluded from the fitting and the interstellar absorption law has been applied. For each fit, the calculated value of $E(U-B)$ has been computed using the relation:

$$E(U-B)_{cal.} = 0.72 * E(B-V) + 0.05 * E^2(B-V)$$

At the minimum difference between the observed and calculated values [$\Delta E(U-B)_{Cal.-Obs.} \approx 0.0$ mag], reddening values and the related distance modulus have been found to be $E(U-B) = 0.18 \pm 0.015$ mag, $E(B-V) = 0.25 \pm 0.015$ mag, and $V-M_v = 13.0 \pm 0.15$ mag. The resulting total visual absorption is then $A_v = 0.75$ mag where the value of the ratio $A_v/E(B-V)$ is taken to be 3.0 as assuming by Garcia et al. (1988).

Comparing the observed (CC) diagram of the cluster Cr 223 with the standard one of Schmidt-Kaler (1982), the intrinsic values of the color indices are estimated for each star as follows: A line parallel to the reddening line has been drawn for each star and the intersection of this line with the *ZAMS*-curve gives the intrinsic color indices $[(B-V)_o \text{ \& } (U-B)_o]$ assuming that the star lies on the main sequence. The slope of the reddening line has been taken to be 0.72 as given by Johnson & Morgan (1953). The stars which are lying below the kink of the *ZAMS*-curve are ambiguous stars and may have two or three possible values. For such stars, the best reading that is consistent with the cluster distance has been taken. The intrinsic visual magnitude $[V_o]$ for each star is determined from the individual reddening estimation.

The two free CMDs of the cluster have been constructed for cluster's members as shown in Fig 1. The solid curved lines represented the standard *ZAMS*-curves of Schmidt-Kaler (1982) fitted to the lower envelope of the points in the two CMDs. The true distance modulus then is $(V-M_v)_o = 12.25 \pm 0.15$

mag , which equals a distance of 2820 ± 190 pc. This distance is found to be in agreement with what obtained by CL91.

The distances of the cluster from the galactic plane (Z), from the galactic center (R_{gc}), and the projected distances from the Sun on the galactic plane (X & Y) have been calculated to be -81 pc, 8.2 kpc, -2.7 kpc and 0.8 kpc respectively.

3. Stellar Density

Counting stars of the cluster through the interstellar medium, particularly in southern sky allow us to define the obscuration clouds before the face of the cluster. The whole studied area of the cluster on AAO-DSS image can be seen in Fig 2.

Applying Wallenquist's (1975) method using the AAO-DSS image of Cr 223, an area of about 3024 arcmin^2 has been covered and more than 2000 stars have been counted. For more details about similar task see Tadross et al. (2002).

A contour map of a grid of 1400 density points has been generated for the cluster region. The stellar density at each grid point has been calculated for the whole area, which appears that it concentrates in south-west direction. It may be a resultant of intrinsic spatial distribution in this area, or caused by some clouds that lie on the face of the cluster. If so, these clouds should affect the stellar densities of the areas behind them and then the concentration of the stellar density in south-west direction is related to the lower values of obscuration as shown in the contour map of Fig 3.

4. Age

CL91 used the bluest color indices to estimate the age of the cluster Cr 223. They found that it has an age of 3.6×10^7 yr, which makes the cluster belonging to the IC 4665 age group of Mermilliod (1981).

In the present work, the age of the cluster has been estimated applying the isochronous curves of Meynet et al. (1993) on the free CMD of Cr 223 [$V_o - (B - V)_o$] as shown in Fig 4. The evolved sequence of the cluster implies that it is in agreement with an age of about 10^8 yr, or younger.

5. Cluster's center

The position of the cluster's center has been determined by counting the stars in two orthogonal rectangular strips using AAO-DSS image of the cluster. The strips were aligned with α and δ directions and divided into suitable bins along their lengths. The densities of the bins are plotted against the central positions of the strips along α and δ respectively; see Tadross et al. (2002). The center of symmetry about the peaks was taken to be the cluster's center as shown in Fig 5. The new center has found to be shifted from CL91's center by 1 arcmin in the northwest direction, i.e. it lies at $\alpha = 10^h : 32^m : 16^s$ and $\delta = -60^\circ : 1' : 12''$, see Fig 2.

6. Angular and Linear Diameter

Knowing the plate scale of AAO-DSS image we can easily see how far the cluster extends and hence estimate the angular diameter and consequently the linear diameter as well. Comparing the chart of Hogg (1965) with the AAO-DSS image of Cr 223, it is found that the members of CL91 are distributed in a circle of about 15 arcmin in diameter. On the other hand, an estimation of the angular diameter can be obtained by examining the radial density distribution of the cluster's stars. For that purpose the projected stellar density of Cr 223 has been a determined counting star in 16-concentric rings from the new center of the cluster. The real stellar density in the cluster's area has been constructed in a histogram as shown in Fig 6. A radius of about 9 arcmin has been obtained which equivalent to 7.4 pc.

7. Luminosity Function

Two histograms have been constructed for the cluster's field and members where the numbers of stars have been counted at intervals of 0.5 mag on V-scale. Half magnitude intervals have been selected to include a reasonable number of stars per magnitude bin and for the best possible statistics in the luminosity function.

The luminosity of each member star of the cluster has been calculated from its visual magnitude. The total luminosity of Cr 223 is calculated to be -4.4 mag summing up the luminosity of every member star it has. However, to show what is called the net observed luminosity function of the cluster, the histogram of the field stars is subtracted from the histogram of the cluster's

members as shown in Fig 7. The absolute magnitude scale appears on the upper axis of that figure with the limiting magnitude:

$$-2.5 < M_v < 1.5 \text{ mag, or } 1.3 < \text{Log } (L/L_{\odot}) < 2.9$$

where $\text{Log } (L/L_{\odot}) = 0.4 * (4.79 - M_v)$ and L & L_{\odot} are the luminosity of the star and the Sun respectively. The high peak lies at $M_v = 0.0$ mag, or at $\text{Log } (L/L_{\odot}) \approx 2.0$.

8. Mass Function and total mass

The mass function of the cluster Cr 223 has been estimated using the theoretical evolutionary tracks and their isochronous of different ages of VandenBergh (1985). The masses of the cluster's members have been estimated applying the polynomial equation that has been developed from the isochronous data at the metallicity factor $z=0.0169$ and $age < 2.5*10^8$ yr.

The mass function histogram has been constructed dividing the mass scale into suitable bins and counting the number of stars at each bin. The high peak lies at $3.75 M_{\odot}$ as shown in Fig 8. On this concept, summing up the stars in each bin weighted by the mean mass of that bin yields the total mass of the cluster that found to be about $190 M_{\odot}$.

9. Conclusions

It is necessary to state that the photometric study of this cluster was depended mainly on the previous preliminary work of CL91 that, of course, has limited number of stars. For that some estimated parameters of the present work, e.g. luminosity and mass functions are also preliminary ones and need more deep study for more precisely determinations. On the other hand, the image of the cluster Cr 223 in the *AAO-DSS* system shows that it needs more extensive CCD observations to enrich the faint members and consequently fills the lower part of the main sequence of the cluster. For comparing the present results with the previous ones of CL91, see table 1.

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I would like to offer my appreciation to the teamwork of the Digitized Sky Survey *DDS* and the Anglo-Australian Observatory *AAO* for providing such very useful images, which serve that kind of work ².

² <http://archive.stsci.edu/dss/acknowledging.html> <http://archive.stsci.edu/dss/copyright.html>

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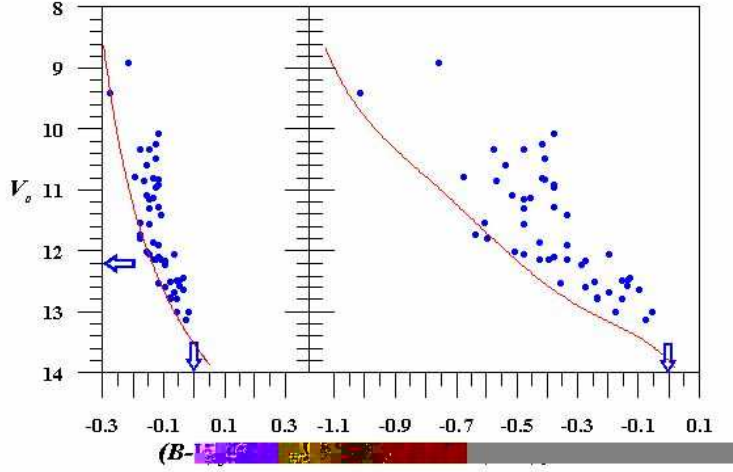


Fig. 1. The free CM diagrams of the cluster's members fitted with *ZAMS* of Schmidt-Kaler (1982). The arrows show the locations of $M_v=0.0$ mag, $(B-V)_o=0.0$ mag & $(U-B)_o=0.0$ mag.

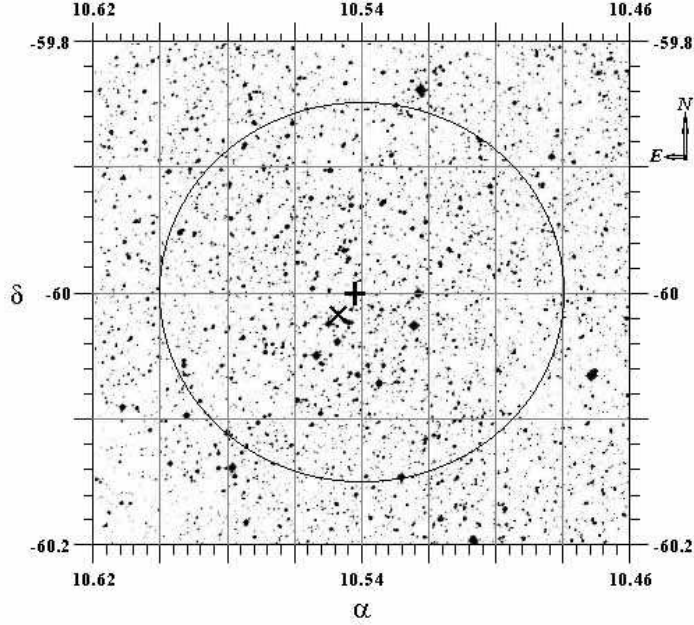


Fig. 2. AAO-DSS image of the cluster Cr 223. "x" refers to the apparent center of the cluster as defined by CL91, "+" refers to the new center of the present work, and the circle defines the whole studied area of the cluster.

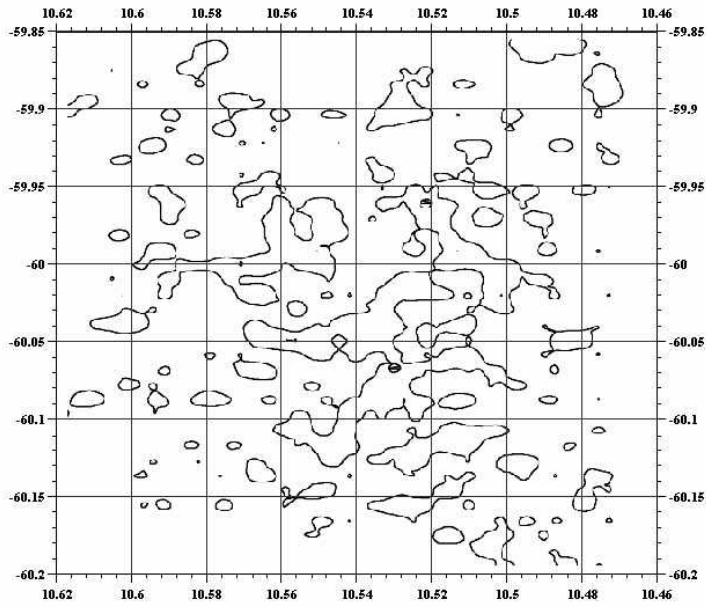


Fig. 3. Contour map of the stellar density of the cluster Cr 223.

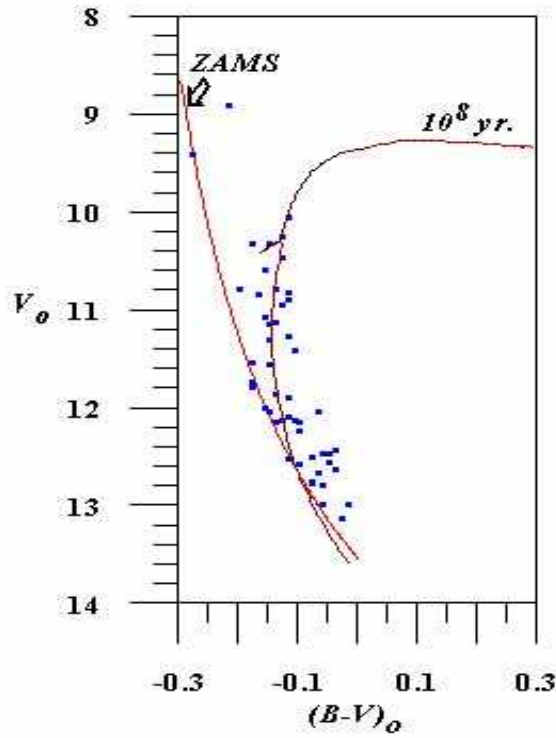


Fig. 4. Age estimation of Cr 223 using the isochronous of Meynet et al. (1993). The evolved sequence of the cluster implies that it has an age of about 10^8 yr, or younger.

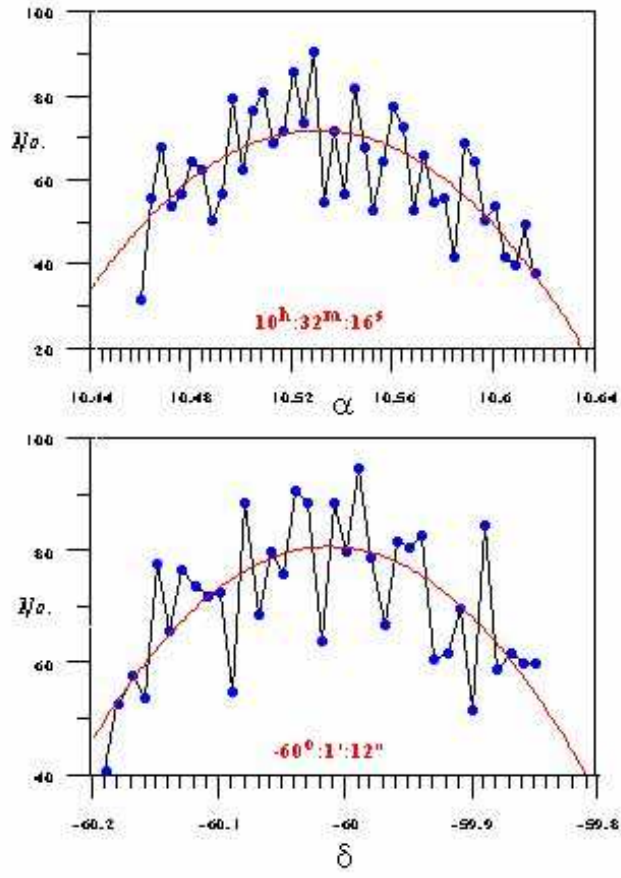


Fig. 5. The center of symmetry about the peaks of α and δ , which have been taken to be the position of the cluster's center.

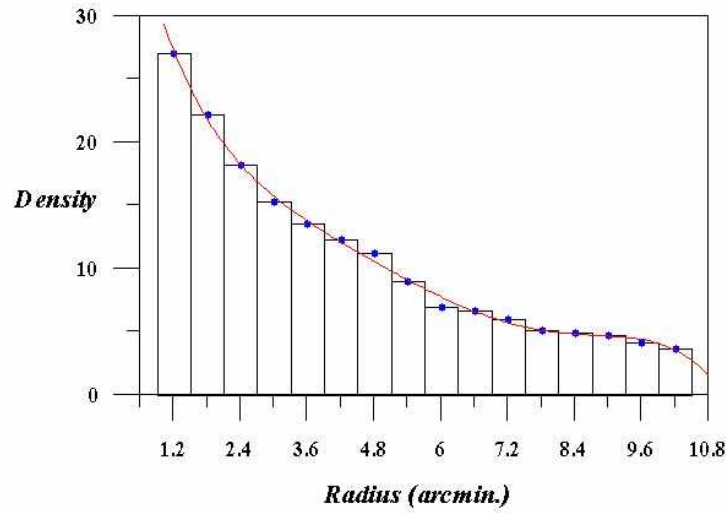


Fig. 6. Radius determination of Cr 223; using the projected density distribution. The radius of the cluster has been taken to be 9 arcmin.

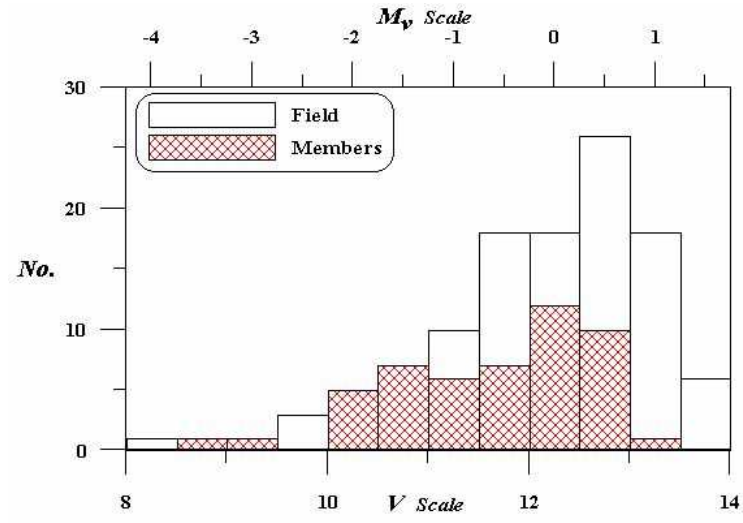


Fig. 7. Luminosity function of Cr 223, the absolute magnitude scale appears on the upper axis.

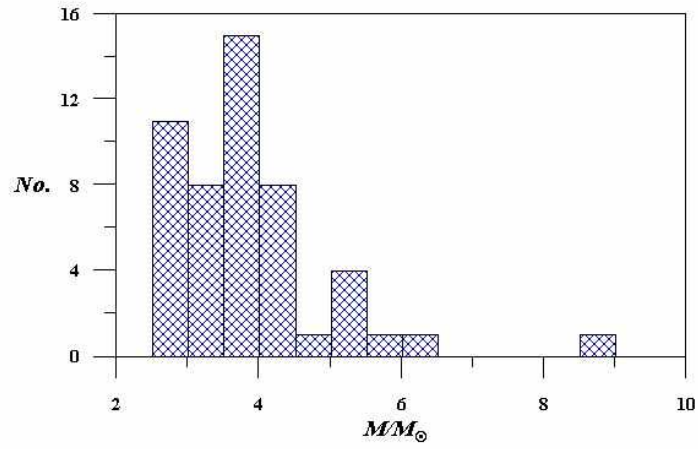


Fig. 8. The mass function of Cr 223, most cluster's members have masses of about 3.75 *M_⊙*

Table 1
On the comparison with CL91.

Parameter	The present work	CL91
Membership	49	46
E(B-V)	0.25 ± 0.015 mag.	0.26 ± 0.03 mag.
E(U-B)	0.18 ± 0.015 mag.	0.19 ± 0.03 mag.
$(V-M_v)_o$	12.25 ± 0.15 mag.	12.26 ± 0.20 mag.
Distance	2820 ± 190 pc.	2830 ± 260 pc.
$A_v/E(B-V)$	3.0	3.0
Z	-81 pc.	-96 pc.
Rgc	8.2 kpc.	—
X	-2.7 kpc.	—
Y	0.8 kpc.	—
Age	$\leq 10^8$ yr.	$3.6 \cdot 10^7$ yr.
Center	$\alpha = 10.5378^h$ $\delta = -60.02^\circ$	Near star no. 77
Diameter	≈ 18 arcmin. (≈ 14.8 pc.)	≈ 15 arcmin.
Stellar density	See the text	—
Luminosity function	Peak lies at $M_v=0.0$ mag.	—
Total Luminosity	-4.4 mag.	—
Mass function	Peak lies at mass of $3.75 M_\odot$	—
Total mass	$\approx 190 M_\odot$	—